

**SEMICONDUCTOR DEVICE WITH MAGNETICALLY PERMEABLE
HEAT SINK**

Field of the Invention

5 This invention relates to semiconductors, and more particularly, to the manufacture of semiconductor devices having heat sinks attached thereto.

Related Art

10 A major issue in semiconductors is heat generation and the need to dissipate that heat. Also becoming important is various kinds of shielding. For example in magnetoresistive random access memories (MRAMs) the logic state of the memory cell is changed by application of magnetic fields. Thus strong spurious magnetic signals can detrimentally alter the state of such a memory. Also RF can detrimentally affect logic. One of the difficulties with such
15 shielding is the coupling of the shielding to a stacked semiconductor device. One of the proposed solutions is to bond wafers together using glass to glass bonding. One difficulty with this approach is that the glass must be very thin to obtain good coupling and planarity of the glass surfaces being bonded, and the wafers must exhibit a high degree of planarity. If there is not sufficient
20 planarity, there is not good coupling.

 Thus, there is a need for heat sinks that overcome these difficulties.

Brief Description of the Drawings

25 The present invention is illustrated by way of example and not limited by the accompanying figures, in which like references indicate similar elements, and in which:

FIG. 1 is cross section of a semiconductor device with an attached heat sink according to an embodiment of the invention;

FIG. 2 is a cross section showing more detail of that depicted in FIG. 1;
and

5 FIG. 3 is a cross section of a semiconductor device with an attached heat sink according to another embodiment of the invention.

Skilled artisans appreciate that elements in the figures are illustrated for simplicity and clarity and have not necessarily been drawn to scale. For example, the dimensions of some of the elements in the figures may be
10 exaggerated relative to other elements to help improve the understanding of the embodiments of the present invention.

Detailed Description of the Drawings

In one aspect, a semiconductor device is attached to a heat sink by glue that is both thermally conductive and magnetically permeable. The glue fills different features in the surface of the semiconductor device so that there is
5 good coupling between the semiconductor device and the heat sink. The glue is filled with magnetic particles so that the glue is magnetically permeable. This is better understood by reference to the drawings and the following description.

Shown in FIG. 1 is semiconductor device 10 comprising a final metal
10 layer 12, an interconnect layer 14, a semiconductor substrate 16, and an interconnect 18. Also shown in FIG. 1 is a thermally conductive/magnetically permeable substrate 22 coupled to semiconductor device 10 by a thermally conductive/magnetically permeable glue layer 20. Substrate 22 can also be considered a heat sink 22. Semiconductor substrate 16 preferably comprises
15 silicon having transistors formed therein so that it is an active semiconductor substrate. Interconnect layers 14 and 18 are for providing interconnections between different transistors and between transistors and power supply voltages. In this example, interconnect layer 14 is shown as being on a top side of semiconductor substrate 16 and interconnect layer 18 is shown as being on a
20 bottom side of semiconductor substrate 16. A final metal layer 12 is on interconnect layer 14 and provides connections for mounting the semiconductor device. Layers 12-22 are originally assembled at the time semiconductor substrate 16 is a semiconductor wafer prior to the time die on the wafer are singulated. This semiconductor device 10 is a magnetoresistive access
25 memory in this described embodiment but may alternatively be another type of semiconductor circuit.

Interconnect layer 18 is formed on semiconductor substrate 16 on the same side of semiconductor substrate as the gates of transistors are formed.

Substrate 22 is attached to interconnect layer 18 by glue layer 20.

Semiconductor substrate 16 is then ground down to be a thinned substrate

5 having a thickness of about 50 microns. Interconnect layer 14 is then formed followed by the last metal layer which forms final metal layer 12. In the preferred case, the final metal layer has bumps which are used to connect to flip-chip package structure. After the formation of final metal layer 12, the resulting device is singulated into individual die ready for packaging as desired.

10 Thus, the formation of device 10 is formed at the wafer level prior to singulation of the individual die.

Glue layer 20 comprises a glue that is both thermally conductive and magnetically permeable. An example of such glue is a nanosilicate underfill available from 3M Corporation. The particular viscosity and type of metal are

15 selectable for the particular manufacturing and device characteristics desired.

In this case, the particles used for the colloid fill are cobalt but could also be something else such as nickel or iron or combinations of any of the three. Also other magnetically permeable materials could be used. The fill particles can be metal coated nanosilica or glass spheres and that coating can be magnetic

20 nickel, cobalt, iron or other magnetic materials. For the designs where magnetic shielding is not desired, then other materials such as carbon, aluminum, metal oxides, and other metals could be used to give varying degrees of thermal and electrical conductivity. The epoxy, bonding agent 34 in this case, in combination with the colloid fill materials is also thermally conductive. The

25 magnetic permeability of the particles used as the colloid fill provide for magnetic shielding from the bottom. In the attachment process, the remaining

portion of semiconductor device 10 would receive shielding. For example, in the case of flip-chip, a magnetic fillet could be used.

Portions of glue layer 20 and interconnect layer 18 are shown in more detail in FIG. 2. The portion of interconnect layer 18 shown in FIG. 2
5 comprises a dielectric layer 24 on glue layer 20, a metal layer 26 on dielectric layer 24, and a dielectric layer 28 on metal layer 26. An opening 30 in dielectric layer 24 results in glue layer 20 be in contact with metal layer 24 through opening 24. Preferably metal layer 26 is for being connected to ground. Particle 32 is an exemplary particle of the colloid fill. Particle 32 has
10 an irregular shape, but there may situations in which another shape, such as spherical, may be beneficial.

Another material that can be useful as glue layer 20 is benzocyclobutene (BCB) with colloidal particles such as those already described embedded therein. BCB itself is not thermally conductive, magnetically permeable, or
15 conductive, but it is a very effective glue. With the embedded particles, it provides for magnetic permeability as well as thermal conductivity. With the colloidal particle density as shown in FIG. 2, glue layer 20 will not be electrically conductive. The colloidal particle density can, however, be increased so that glue 20 can be electrically conductive. In such case the
20 resulting glue is electrically conductive, thermally conductive, and magnetically permeable. This electrical conductivity is beneficial if it is desirable to make electrical contact between substrate 22 and the ground of semiconductor substrate 16. A thickness of 1 to 2 microns is a desired thickness for glue layer 20. By being this thick and being spun-on, glue layer 20 provides for good
25 coupling even if the surfaces of interconnect 18 and substrate 22 are not fully planar. In fact glue layer 20 provides for the opportunity to make direct contact

between glue layer 20 and metal layer 26. The desired thermal conductivity of glue layer 20 is at least 1 watt/meter-degree where degree is stated in Kelvin. The desired magnetic permeability is balanced against the ability to spin the glue because the viscosity increases with increasing metal content. The permeability will increase with metal content, and the fill epoxy will be permeable in proportion to the magnetic material contained within the glue.

An effective material for substrate 22 is silicon carbide coated with nickel. Silicon carbide provides good thermal conductivity, and nickel provides good magnetic permeability. Other magnetic materials such as cobalt and iron can be used. If glue layer 20 is sufficiently magnetically permeable for the particular application, then the nickel coating may not be necessary. In such case substrate 22 would not itself be magnetically permeable. The silicon carbide material is beneficial for this application also because of its coefficient of thermal expansion (CTE), which can be effectively matched to that of silicon.

Shown in FIG. 3 is a semiconductor device 40 comprising a final metal layer 42, an interconnect layer 44, a semiconductor substrate 46, an interconnect layer 48, a semiconductor substrate 50, and an interconnect layer 52. Similar to semiconductor device 10 of FIG. 1, a thermally conductive/magnetically permeable substrate 56 is coupled to semiconductor device 40 at interconnect 52 by a conductive/magnetically permeable glue layer 54. This substrate 56 and glue layer 54 are the same as substrate 22 and glue layer 20 of FIG. 1. Semiconductor device 40 is different from semiconductor device 10 by having an additional semiconductor substrate and interconnect layer. This shows the applicability of glue layer 54 and substrate 56 to three dimensional wafer structures. The interface between glue layer 54 and

interconnect layer 52 may have a portion that is the same as that shown for the interface between glue layer 20 and interconnect layer 18 shown in FIG. 2.

The formation process follows that for the structure of FIG. 1 through the formation of interconnect layer 14 which is analogous to interconnect layer 48.

5 After the formation of interconnect layer 48, semiconductor substrate is applied followed by the formation of interconnect layer 44 and then final metal layer 42. This structure of FIG. 3 is thus originally formed at the wafer level then singulated.

In the foregoing specification, the invention has been described with
10 reference to specific embodiments. However, one of ordinary skill in the art appreciates that various modifications and changes can be made without departing from the scope of the present invention as set forth in the claims below. For example, other materials than those described for the various layers may be used. Additional semiconductor substrate layers may be used. The
15 semiconductor substrates may be different from silicon and may be different from each other as well. The semiconductor substrates may be considered to have just one or more than one integrated circuit present. In practice the substrates are bonded together as wafers and then singulated but this could be done in a different way. Accordingly, the specification and figures are to be
20 regarded in an illustrative rather than a restrictive sense, and all such modifications are intended to be included within the scope of present invention.

Benefits, other advantages, and solutions to problems have been described above with regard to specific embodiments. However, the benefits, advantages, solutions to problems, and any element(s) that may cause any
25 benefit, advantage, or solution to occur or become more pronounced are not to be construed as a critical, required, or essential feature or element of any or all

the claims. As used herein, the terms "comprises," "comprising," or any other variation thereof, are intended to cover a non-exclusive inclusion, such that a process, method, article, or apparatus that comprises a list of elements does not include only those elements but may include other elements not expressly listed
5 or inherent to such process, method, article, or apparatus.